# METHOD AND SYSTEM FOR MONITORING A RECIPROCATING COMPRESSOR

The present invention relates to a method and a system for monitoring a reciprocating compressor.

In particular, the present invention relates to a method and a system for monitoring a reciprocating compressor which enables a real-time and predictive diagnosis of the faults and malfunctions of the compressor to be made.

The compression of gas requires various types of machine, including reciprocating compressors and their corresponding fittings, accessories and operating systems. Reciprocating machines have the advantage of high efficiency and flexibility of operation.

As is known, a reciprocating compressor is a processing machine whose output is a compressible fluid (gas) at a pressure greater than that at which the fluid was received.

The reciprocating compressor operates with at least one cylinder which is made to communicate at appropriate moments with a delivery environment or with an intake environment; the fluid is drawn in from the intake

environment and then compressed, and finally discharged to the outside.

In particular, reciprocating compressors operate with variations of volume of a working chamber, obtained by the rectilinear movement of a rigid body along the generatrices of a cylindrical cavity, and can be operated by means of a crank mechanism for converting a continuous circular motion, such as that generally provided by electric and thermal motors, to a reciprocating motion, as required in this particular case.

An example of a reciprocating compressor is described in patent application EP 1,184,570 in the name of the present applicant.

It is known that reciprocating compressors now yield extremely high levels of availability, owing to the use of advanced materials, design and simulation methods, and plant automation and control systems.

Recent automated systems make a considerable contribution to new installations and to the modernization of existing systems in terms of safety, ease of operation and monitoring of the efficiency of the machinery, and create competitiveness in the chemical, petrochemical and general industrial sectors.

An article with the title "Controllo e diagnostica dei compressori alternativi" ["Monitoring and diagnosis of reciprocating compressors"] published in the journal "Manutenzione tecnica e management" in September 2002 describes how diagnostic systems make a real contribution to improved operating efficiency and availability.

The applicant has observed that, in known monitoring systems, data are acquired by measuring process variables of the compressor and are simply compared with fixed reference values.

The applicant has tackled the problem of increasing the significance of the information obtained from the data acquired during the operation of a reciprocating compressor, for monitoring the correct operation of the said compressor.

The applicant has provided a system and a method for monitoring a reciprocating compressor in which the measured data are processed and subsequently compared with previously stored data correlated with predetermined anomalies in a matrix which contains critical values of parameters relating to the operating state of the compressor. Thus the comparisons which are made enable any anomaly to be identified with a greater

probability, since it is discovered by an analysis of the variations of the parameters encountered; for this purpose, the system according to the present invention displays in a suitable way any cause of the malfunction.

A first aspect of the present invention relates to a method for monitoring a reciprocating compressor, comprising the following steps:

- receiving a plurality of signals corresponding to parameters relating to the operating state of the compressor,
- comparing the measured values of these parameters with critical values contained in a database,
- sending a signal according to the match between the measured values and the critical values, the signal representing an anomaly of the operating state of the compressor.

A further aspect of the present invention relates to a system for monitoring a reciprocating compressor, comprising a unit for measuring parameters relating to the operating state of the compressor, a processing unit for comparing the measured values of the parameters with critical values contained in a database

associated with the said processing unit, and for sending a signal according to the match between the measured values and the critical values, this signal representing an anomaly of the operating state of the compressor.

The characteristics and advantages of the monitoring method and system according to the present invention will be made clearer by the following description, provided by way of example and without restrictive intent, of one embodiment with reference to the attached figures, in which:

Figure 1 is a block diagram of the monitoring system according to the present invention applied to a reciprocating compressor; and

Figure 2 is a block diagram of the operations carried out in a processing unit of the system according to the present invention.

With reference to the aforesaid figures, the system according to the present invention comprises a measuring unit 3 which receives signals from a plurality of sensors associated with a reciprocating compressor 2.

The signals from the sensors and the manually entered data represent parameters relating to the operating state of the compressor.

The system also comprises a processing unit 4 which communicates with the said measuring unit and a display unit 5 associated with the said processing unit.

The said processing unit comprises a microprocessor and at least one storage device.

This processing unit also contains within it a design database containing design parameters of the compressor. These design parameters are obtained, for example, by processing carried out with a program for designing reciprocating compressors.

The system according to the present invention comprises at least one program for monitoring these parameters relating to the operating state of the compressor and at least one diagnostic program, which, on the basis of the acquired data, detects an anomalous condition of the operation of the compressor.

The said monitoring program controls the measuring unit in such a way as to determine the parameters which are measured from the compressor by means of the sensors, the parameters entered manually by an operator, and the design parameters contained in the said database.

The said processing unit comprises at least one database, preferably arranged in the form of a matrix of previously stored data.

This matrix relates to a plurality of anomalies which can be identified, each of these being associated with a row of the matrix, while the columns of the matrix represent the parameters relating to the operating state of the compressor.

In particular, each row of the matrix relates to a specific anomaly identified by predetermined critical values of these parameters.

The diagnostic program operates in the following way.

When the parameters measured by the sensors and those entered manually by an operator have been received by means of the said monitoring program, a comparison is made between the measured parameters and the corresponding values of the critical parameters contained in each row of the matrix of anomalies.

Figure 2 is a block diagram of the operations carried out in a processing unit of the system according to the present invention.

In particular, the said operations comprise the reading of all the necessary data, including a first step 31 of reading from the sensors associated with the

reciprocating compressor, carried out by the said measuring unit 3, a second step 32 of reading the manually entered data, and a third step 33 of reading reference parameters stored in the said processing unit.

Additionally, other data to be compared are obtained from the design specifications 34 of the compressor, and are compared, in a preliminary comparison step 35, with the data 31 measured by the sensors.

On the basis of the measured data and the design specifications, the design program determines in this step whether or not there is conformity with the design conditions, and, if the outcome is positive, proceeds with the diagnostic program; if the outcome is negative, it sends a first display message 39 relating to the failure to conform to the design specifications. The results of this preliminary comparison are used as inputs for a design program for reciprocating compressors 36. The outputs of this design program form further comparison parameters.

After the step of reading all the data, a step of comparison is carried out, comprising a first comparison 37 made between the data measured by the sensors 31, the manually entered data 32, the data

processed by the design program 36 and the reference parameters 33, and a second comparison made between the manually entered data 32 and the absolute values 33.

The said first comparison 37 analyses the reference parameters with respect to the data processed by the design program and the data measured by the sensors, and to those entered manually with respect to the said reference parameters.

The said second comparison 38 analyses the reference parameters with respect to the data measured by the sensors and to those entered manually.

Preferably, if the operation is correct, both comparisons cause a simple message to be sent, indicating correct operation.

If an anomaly is detected, for example because some measured data deviate too far from the reference parameters, a search 41 is made in the said matrix of anomalies 40 until a row meeting the processed conditions is found. At this point, the diagnostic program advantageously generates a message 42 which indicates the characteristics of the encountered anomaly.

Examples of the parameters relating to the operating state of the reciprocating compressor according to the

present invention are the intake pressure of the 1st stage of the compressor, the intake temperature of each stage, the delivery pressure of the last stage, the composition of the gas, the ambient temperature, the speed of rotation of the compressor and the temperature of the cooling fluid at the inlet and outlet of the compressor cylinders.

Preferably, mechanical parameters which can simulate the machine in question in the best possible way (rod length, bore, stroke, etc.) are also measured.

The aforesaid parameters, except for the mechanical ones, are advantageously processed by the design program to produce operating parameters such as the gas flow rate, the delivery pressure of each stage except the last, the delivery temperature of each stage, the power consumption and the forces acting on the crank mechanism.

These results, when appropriately compared (with the aforesaid reference parameters or with values obtained from mathematical relations or with the corresponding values measured in the field) will make it possible to determine whether the machine is operating in the design or safety conditions.

The comparison will make it possible to determine whether a variation found in the operating parameters is due to a "physiological" phenomenon, in other words one due to input factors, or a "pathological" phenomenon, in other words one due to anomalies.

Therefore, when the variations due to "pathological" phenomena have been "selected", the program will "fill in" the said predefined matrix of anomalies.

For example, the matrix shows approximately 60 anomalies or causes of faults, such as fracture of a valve, wear of piston rings, etc., in the rows, while it shows the variations of the parameters in the columns (in a number equal to the number of parameters being monitored).

Under each variation, the rows corresponding to the possible anomaly or cause which may have caused this variation are "flagged".

By subsequently checking the rows of the aforesaid matrix, it is possible to identify with greater probability the anomaly which may have caused the variations of the parameters which have been encountered.

The matrix also contains the variations of parameters such as the temperatures of the valve covers, the

temperatures of the main bearings, etc. which are not processed by the design program but which are the result of anomalies.

The anomalies which have been encountered are then displayed on the display unit of the system.